A remote sensing investigation of elevated sub-horizontal topographic surfaces in the Wichita Mountains, Oklahoma

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A REMOTE SENSING INVESTIGATION OF ELEVATED SUB-HORIZONTAL TOPOGRAPHIC SURFACES IN THE WICHITA MOUNTAINS, OKLAHOMA

by

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ABSTRACT

Multiple elevated horizontal to sub-horizontal topographic surfaces are present in the Wichita Mountains, Oklahoma. Elevated topographic surfaces, developed primarily on granite bedrock with gentle slopes of 0.5 to 7°, were investigated using 1) Digital Elevation Models (DEMs) extracted from NAD 27 UTM coordinates, 2) Google Earth imagery, and 3) USGS topographic maps. In the western Wichita Mountains prominent topographic surfaces at elevations of 720 ± 5 m, 685 ± 5 m, and 660 ± 5 m are well preserved on at least four different mountains (e.g., Solder’s Peak, King Mt.) and can be correlated with similar surfaces on at least seven different mountains (e.g., Mt. Scott, North Mt.) in the eastern Wichita Mountains. A less well developed surface at 585 ± 5 m is present in the eastern Wichita Mountains and may not be preserved in the western Wichita Mountains. These surfaces are interpreted to be relict pediments or remnants of a more extensive peneplain subsequently dissected as a result of long term time integrated changes in base level, climate, and/or tectonic uplift. Correlation of elevated sub-horizontal surfaces between the western and eastern Wichita Mountains suggests the Wichita Mountains basement behaved as a coherent crustal block since Mid Cenozoic. The presence of multiple elevated, sub-horizontal, regional topographic surfaces throughout the Wichita Mountains complicates direct correlation of these surfaces to the Southern High Plains peneplain using either a linear regression or an exponential fit along a line of projection. Thus, a finer resolution of the timing for individual elevated surfaces in the Wichita Mountains needs to be established.
ACKNOWLEDGMENTS

My sincere appreciation goes to my advisor, Dr. John Hogan, for all I have learned and for his invaluable support throughout my studies. This thesis is due to his initiative and encouragement. His words can always inspire me and bring me to a higher level of thinking. What I learnt from him is not just how to work on a research to meet the graduation requirement, but how to think and work as a scientist. Moreover, as a non-English writer, I get a tremendous help from Dr. Hogan to improve my writing skills for scientific purposes. His careful supervision and reading of my drafts brought my thesis to finalization. I would like to thank my committee members Prof. J. David Roger and Prof. Alan Chapman for their interest in my work and academic support and input.

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1. INTRODUCTION

1.1. PEDIMENT

1.1.1. Definition of Pediment. The term “Pediments” was first used by McGee (1897) as piedmont plains cut in bedrock. Now pediment refers to sub-horizontal, low-relief bedrock erosional surfaces at the base of a mountain range. On granitic terrains, pediments are typically inclined from 0.5° to 7° with respect to horizontal, and commonly 0.5° to 2.5° (Twidale, 2005). The piedmont angle is the sharp slope between the mountain front and pediment base (Fig. 1). This junction is also necessary for the definition of pediment because it indicates the process of backwearing and etching and demonstrates the location where fluvial erosion starts to incise (Twidale, 2005). The development of pediments is restricted by the piedmont angle and alluvium (Fig. 1). The term “Knik” Point is introduced here to identify abrupt changes in slope within topographic profiles (Fig. 1). Knik points are commonly associated with relict pediments and the elevation of knik points on different mountains in the Wichita’s is compared.

Figure 1.1 Simplified cross section of a pediment surfaces in Wichita Mountains.
1.1.2. Classification of Pediment. Several classifications for pediments exist. One common classification is dependent on the lithologic environment, including sedimentary pediment, mantled pediment, and platform (rock pediment) (Twiddle, 2005). Another general classification is based on the nature of pediment surfaces (Gilbert, 1877; Miller, 1950). If the pediment surface is formed on a more resistant rock in contact with less resistant rock, this type of pediment is called a planation surface. Whereas, if the surface is formed on the same lithology as that of the mountain range adjacent to it, this type of pediment is called a rock pediment. Elevated erosional surfaces carved into granite in the Wichita Mountains are best classified as rock pediments and herein referred to simply as pediments.

1.1.3. Formation of Pediments. The origin of pediments is debatable. The geomorphic understanding of pediment formation and evolution focuses on two processes: 1) parallel scarp retreat followed by lateral corrosion of sheet wash (Lawson, 1915; Bryan, 1927; King, 1949, 1966) and 2) down wearing and etching of surrounding rock (Oberlander, 1972; Twidale, 1993, 2005, 2013). The scarp retreat hypothesis proposes that mountain fronts erode most by slope retreat, leaving behind an alluvium-mantled bedrock surface. Pediments are formed and then exhumed from beneath alluvium by tilting and erosion.

Alternatively, pediments are suggested to be formed by a two-stage process of weathering and erosion (Twidale, 2013). In the first stage, the granite block undergoes fracture-controlled subsurface chemical weathering as meteoric water, chemicals, and biota penetrate the bedrock along joints and fractures. Granitic rocks are particularly vulnerable to this process because of the preferential weathering of feldspar and mica on the surface (Twidale, 2005). The granite adjacent to the fractures weathers faster, leaving a corestone in the center. In the second stage, the weathered bedrock and regolith cover is stripped away by stream systems, exposing the weathering front and flat surface. Rivers developed in lower gradients may remove debris and wash the regolith away. The boulders left on pediments may serve to demonstrate an earlier period of subsurface moisture attack during topographic stability (Twidale, 2005).
1.1.4. Geologic Significance of Pediments. Preserved bedrock pediments serve as a record of regional uplift or subsidence in tectonic history (Yildirim, 2013). Although the exact mechanism of pediment formation is unclear, a distinct period of tectonic quiescence is necessary, allowing the backwearing or the two-stage etching to occur. The low-relief geomorphic property of pediments reflects the fluvial incision processes within a stable ultimate base level. Therefore, pediments can be employed as geomorphic markers of base level stability as well as landscape response to changes in regional tectonics and/or climate.

The occurrence of pediments is common in, but not limited to arid or semi-arid environments. They are considered to be a characteristic of desert areas, especially within low or middle latitude zones, where coarse and resistant debris can be provided to form pediments as well as survive chemical weathering (Twidale, 1981). Also, the presence of pediments suggests the basin associated with the pediments is hydrologically open (Strudley, 2007). As a result, pediments can be used to constrain the climate and hydrogeological condition when they form.

1.2. SUB-HORIZONTAL SURFACES IN THE WICHITA MOUNTAINS OF OKLAHOMA

The sub-horizontal surfaces in the Wichita Mountains of Oklahoma were first mentioned by Taylor (1915) as remnants of a post-Permian peneplain. Swanson (1987) defined these surfaces as pediments, concluding the granite platforms were pediments cut to either a certain local or a regional elevation. Harrell (1993) investigated the presence of elevated pediments in the western Wichita Mountains on four mountains in the vicinity of Lake Altus, Oklahoma and noted the best developed platforms are on the southern and western sides of the hills. He proposed the major pediments surfaces are present at elevations of 643 m on Tepee Mountain and at 655 m on King, Flattop, and Soldiers Peak. Using a linear extrapolation (with a slope of 1.90m/km), the elevations of these four surfaces matched well with the projected elevation of the sloping Southern High Plains surface into Oklahoma. Thus, Harrell (1993) attributed these surfaces to be relicts of the Southern High Plains that has retreated westward 180 km since the late Pliocene and early Pleistocene. Based upon the same regression, Harrell (1993) did not recognize
the presence of pediments in the eastern Wichita Mountains and suggested that such surfaces never developed on the granite bedrock as it remained buried beneath the Permian Post Oak Conglomerate.

Figure 1.2. Photo of Elk Mountain of the eastern Wichita Mountains. Two relict pediments are preserved at distinct elevations (shown in green and yellow) in this photo. The red part is the basement in the Wichita area.

Recent investigations of topographic surfaces in the both the western and eastern Wichita Mountains utilizing Digital Elevation Models (DEMs) have suggested the presence of multiple elevated topographic surfaces in both the western and the eastern Wichita Mountains (Fig. 2) (Crew and Hogan, 2004; Jerris and Hogan, 2008). DEMs are an attractive approach to investigate these surfaces as they provide a means of identifying
and characterizing potential pediments. The purpose of this paper is to identify and characterize elevated sub-horizontal topographic surfaces in the western and eastern Wichita Mountains utilizing DEMs, Google Earth Imagery, and topographic maps to test and establish 1) if these surfaces meet the criteria for pediments, 2) the elevations at which these surfaces are preserved, and 3) evaluate possible correlations between well-developed surfaces in the western Wichita Mountains with those present in the eastern Wichita Mountains.

The presence of multiple elevated sub-horizontal topographic surfaces that can be correlated across the Wichita Mountain block places constraints on the interpretation of the tectonic history of the southern Mid-Continent and on the processes leading to the development of pediments in this region. These surfaces indicate that both the western and eastern Wichita Mountains were subjected to the same conditions resulting in the formation of distinct pediments at distinct elevations. In addition, these relict pediments have been preserved since their formation and have maintained the same relative elevation to one another, thus placing constraints on tectonic activity as well as requiring revaluation of their genetic relationship to the Southern High Plains surface.
2. GEOLOGIC SETTING

The Wichita Mountains of southwest Oklahoma cover an area of approximately 6,500 km² (Fig. 3). The Wichita Mountains are informally subdivided into the Western and Eastern Wichita Mountains, which are two inselbergs. Both western and eastern Wichita Mountains are ranges and ridges that stand abruptly from the surrounding plains, whereas the eastern Wichita Mountains consisted of ranges of hills and isolated valleys. The Western Wichita Mountains include Flattop Mountain, Tepee Mountain, King’s Mountain, and Soldier’s Mountain, extending about 25 km southeast from the town of Granite. The Eastern Wichita Mountains is a northwest-southeast trending series of resistant bedrock promontories, including Elk Mountain, Geronimo Ridge, Moko Mountain, Mountain Pinchot, Mount Scott, North Mountain, and Blue Mountain.

Figure 2.1. Hill shade map of Wichita Mountains and study area, showing both Western and Eastern Wichita Mountains with elevation values.
2.1. TECTONIC HISTORY

The tectonic history of Wichita Mountain is complex (Price et al., 1998). The gabbro and basalt in Wichita Mountains were first produced by early Cambrian intraplate magmatism in the Southern Oklahoma rift zone (Hogan, and Gilbert, 1998; Hanson et al., 2013). This Cambrian igneous activity also came along with a widespread voluminous felsic magmatic activity to form the Carlton Rhyolite and Wichita Granite Group within a northwest-southeast trending zone (Fig. 4) (Hogan and Gilbert, 1998; Hanson et al., 2013). The two groups present as the earliest igneous suite of the Wichita Mountains yielded the zircon ages of ~539-530 Ma (Hanson et al., 2013).

Following cessation of Cambrian extensional tectonics and magmatism, a regional subsidence started from Late Cambrian to the Mississippian (Gilbert, 1989). Basins in southern Oklahoma in the last half of the Mississippian rapidly subsided, resulting in thick sedimentary deposits (~4-8 km) that consist predominantly of shale, “Mississippi lime” and sandstone (Donovan, 1982). This aulacogen basin underwent differential subsidence relative to the surrounding area and would have been similar to other intracratonic basin such as the Dniepr-Dnets aulacogen, and present day Michigan or Illinois Basin (Keller and Stephenson, 2007).

In Pennsylvanian time, a plate collision occurred between the North American plate and either Gondwana or an intervening microplate, giving rise to the northeast-trending Appalachian orogenic system and possibly the ancestral Rocky Mountains (Latham, 1970; Kluth, 1986; Ye et al., 1996). This compressional event in southern Oklahoma led to the reactivation of normal faults as reverse faults, thus the Wichita Mountains igneous complex was uplifted and unroofed by erosion. Material derived from the eroded basement was deposited locally as alluvial fans and conglomerate while sandstone and shale were received by the Anadarko Basin to the north (Fig. 3), resulting in ~12 km thickness of sediments (Perry, 1989; Lee, and Deming, 1999; Lee, and Deming, 2002). During this time, the Wichita Mountains underwent substantial erosion.

Following the Pennsylvanian basin inversion and uplift of the Wichita Mountains, western Oklahoma was covered by a shallow inland sea in Early Permian. During this time the Wichita Mountains were buried unconformably by Permian and post-Permian sediments (~2 km) from the Ouachita Mountains to the east and locally derived units as
well, resulting in a veneer of clasts on the present-day Wichita Mountains (Gilbert, 1982; Price et al., 1998;). This rugged Permian topographic surface composed of Post Oak Conglomerate and igneous rocks is still presented today as “fossil topography” (Gilbert, 2002). The shape of clasts of granite can be interpreted as being formed by spheroidal weathering followed by uplift of ~300-350 m before local transport (Gilbert, 2002). This Permian surfaces and clasts complicate interpretation of surfaces in the Wichita Mountains as this area clearly has had a long and complex history involving several cycles of burial, uplift, and erosion. From Tertiary till today, uplift of the Rocky Mountains caused a broad uplift of Oklahoma and a new stage of re-exhumation in the Wichita area (Winkler et al., 1999; Carter et al., 1998; Corrigan et al., 1998).

2.2. STRUCTURE

Fractures and faults are well developed in Wichita Mountains (Appendix. 7). Most of the fractures dip at high angle or are vertical with a strike orientation of N70°W (Gilbert, 1982). These surface lineaments clearly identify a fracture system cutting into the Wichita Granite Group and Roosevelt Gabbro Group (Fig. 4). Three major faults were developed in Wichita area: the Burch Fault, the Waurika-Muensters Fault, and the Meers Fault. Among these faults, the Meers Fault, extending along the northeast side of the Wichita Mountain, records significant movement (Budnik, and Davis, 1985).

The tectonic setting contributing to displacement along these structures is controversial. Most of the structural elements in this region were attributed to compression in late Mississippian and ending in Early Permian time as a result of continental collision related the Ouachita Orogeny and formation of Pangea (Viele and Thomas, 1989). However, this explanation fails to explain the geometry and orientation of Ouachita Deformation Belt in the southern Oklahoma (Winkler et al., 1999). Alternatively, Ye (1996) suggested that the NW-trending subduction zone located in northern Mexico could possibly trigger the NW-trending uplifts in the Ancestral Rocky Mountains and Wichita Mountains during in late Mississippian.
Figure 2.2. Geologic map of Wichita Mountains and study area (From Jonathan Price pers. comm. 2014). Sub-horizontal surfaces preserved on Wichita Mountains developed on granite, which is vulnerable to moisture and streams.
3. METHOD

3.1. RECOGNITION AND DEFINITION OF PEDIMENT

Pediments in the Wichita Mountains are recognized and defined by evaluating four criteria utilizing DEMs. Adhering to the general definition, a tolerance for the dipping angle of pediments of 0.5 to 7° is applied (Twidale, 2005; Royse and Barsch, 1971). The difference in elevation across typical pediments in Wichita Mountains is 10-15 m. Therefore, the scale of the pediments can be calculated as at least 81 meters from the piedmont angle to the rim (Fig. 1). At the same time, the piedmont angle is also necessary because it indicates the backwearing point of pediment formation. This characteristic is also the major difference between pediments and other similar terrains like peneplain and alluvial fan. Based upon my observation, most of the pediments preserved in Wichita area occur in the Cambrian Wichita Granite Group (Fig. 4), even though they may be covered with alluvium or grounded granitic or gabbroic boulders. Herein I limit pediments in Wichita Mountains to the Cambrian bedrock. Together with all the factors above, the pediments in my model are required to meet four conditions: 1) a dipping angle from 0.5 to 7°, 2) a minimum scale of 84 m wide, 3) association with piedmont angle, and 4) underlain by the in the Wichita Granite Group.

3.2. ELEVATION DATA COLLETION AND PROCESSING

The mapping methodology employs integration and draping of elevation data with a GIS database. DEMs used in this study were derived from the USGS National Elevation Dataset (NED) at a resolution of 1/3 arc-second (~9 meters). This tolerance meets well the desired level of precision required for digitizing and analysis. The elevation data were processed through the software of ENVI and ARCGIS. Specifically, DEMs are established by the combination of contour maps, topographic profiles and three dimensional surface views for each mountain in Wichita area. The contour map was constructed with the interval of 10 m. Three dimensional views were built of texture surface of pediments colored with purple-red stripe at a vertical exaggeration of 3.0.
4. RESULTS

4.1. DISTRIBUTION OF PEDIMENTS IN WICHITA MOUNTAINS

More than 30 pediments are recognized and mapped throughout Wichita Mountains (Table 1 and Table 2). Pediments in the western Wichita’s are in a scale of 100-300 m², whereas, the ones in the east are more extensively developed and cover a larger area (more than 300 m²). The elevation distribution of the pediments is from 550 to 750 m. The basement below these pediments is a regional flat plain (~440m) covered by quaternary sediment (Fig. 4).

4.2. PEDIMENTS IN THE WESTERN WICHITA MOUNTAINS

Elevated pediments are well developed on the four mountains selected for investigation in the western Wichita’s (Table 1). The characteristics of these pediments on the individual mountains are discussed in the following paragraphs.

**King Mountain** - Two pediments are preserved on King Mountain at elevations 657 m (WKP1) and 719 m (WKP2) respectively (Fig. 5). Pediment WKP1 is more extensive (~ 400 m²) and nearly surrounds the peak of King Mountain and is also found on a lower hill to the southwest (Fig 5. A1, A2). Pediment WKP2, found just below the peak of King Mountain, is less extensive (~150 m²) and less obvious in the contour map and 3D view (Fig. 4). Both pediments and an intervening knik points are visible on a northeast-southwest topographic profile across King Mountain (Fig 5. A3).

**Soldier’s Mountain** - Two elevated pediments are also well preserved on Soldier’s Mountain 4.5 km to the southeast of King Mountain. The pediments at 660 m (WSP1), one of the best preserved and extensive (500 m²) pediments in western Wichita Mountains, is readily apparent on the topographic map. On the 3D surface view this pediment nearly surrounds the entire peak (Fig. 5 B1, B2). Pediment WSP2 occurs at a higher elevation (689 m) and similar to the pediment on King Mountain occupies a considerably smaller area (~100 m²). Both pediments are clearly visible on a northeast-
southwest topographic profile across Solders Peak with the pediment at 660 m showing up well on both sides of the peak (Fig. 5 B3).

Table 4.1. The elevation of pediments and knik points in Western Wichita Mountains.

<table>
<thead>
<tr>
<th></th>
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<th>Soldier’s Peak</th>
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<td>99°17'37.31&quot;W</td>
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**Flattop Mountain** - Near the summits of Flattop Mountain are conspicuous pediments at an elevation of 659 m (WFP1). It occurs widely on all three peaks of Flattop Mountain, covering more than 1000 m². From the topographic profile (Appendix. 6), we can see the WFP1 is a discontinuous, but typical horizontal pediment surface. The scattered distribution of WFP1 Pediment is a reflection of this surface having been highly dissected by the Red River.

**Teepee Mountain** - Tepee Mountain is an isolated hill that stands 3.4 km northeast away from other three mountains. Pediments on Tepee Mountains are less well developed. The most obvious one is WTP1, which in comparison to other pediments in
the western Wichita Mountains, occurs at a much lower elevation (574 m). WTP1 is preserved on the southern summit of the mountain with a scale of 100 m². The peak and several knik points (smaller sub-horizontal surfaces) are found at similar elevations as the pediments on the other mountains in the western Wichita’s.

Figure 4.1. Digital elevation model of Western Wichita Mountains, showing topographic profiles along the traces in King’s Mountain and Soldier’s Peak respectively. A1, B1) Topographic map with a contour interval of 10 m; A2, B2) Three dimensional surface view color with red-purple stripe. A3, B3) Topographic profile demonstrated along the line of section in A1, B1.
4.3. PEDIMENTS IN THE EASTERN WICHITA MOUNTAINS

Elevated pediments are also preserved, to various extents, on numerous mountains in the eastern Wichita Mountains (Table 2). The characteristics of these pediments on the individual mountains in the eastern Wichita’s are discussed in the following paragraphs.

**Moko Mountain** - On Moko Mountain, the prominent pediments are present as EMP1 (663 m) and EMP2 (681 m). These two distinct pediments are visible on the 3D surface view (Fig. 6 B2). EMP1 and EMP2 vary in size on the different summits of the hills known as Moko Mountain, but collectively they occupy 450 m² and 800 m² respectively. Both pediments can be recognized as bald, steep-sided flat surfaces on topographic profile AB and CD across Moko Mountain (Fig. 6 B3, B4).

**North Mountain** - Three major pediments can be discerned on North Mountain, 2.25 km north of Moko Mountain. Similar to the elevated pediments in western Wichita Mountains, these pediments occur at elevations of 659 m (ENP2) and 685 m (ENP3). ENP2 and ENP3 are typically well-preserved pediments (330 m² and 580 m² respectively) but locally have been incised by streams exploiting prominent fracture orientations. Based upon the topographic profile AB (Fig. 6 A3), the slope of ENP3 and two knik points are dipping gently to the northwest. A well-developed (~700 m²) pediment ENP1 at a lower elevation of 590 m is recognizable at northern end of North Mountain.

**Elk Mountain and Geronimo Ridge** - Pediments are also well developed on Elk Mountain and Geronimo Ridge (see Fig. 2 and Appendix 6). On Elk Mountain, pediments are best preserved on the northern hills and are dissected along a few visible NE-SW trending fractures. The three pediments are preserved at the elevation of 685 m (EEP1), 678 m (EEP2) and 657 m (EEP3). EEP2 and EEP3, developed on the same summit, cover ~500 m² and 250 m² respectively. EEP1 (~600 m²) occurs in isolation on a peak 300 m north of Elk Mountain. Along the north-south profile pediments can be seen to have been incised and reshaped by stream valleys (Appendix 6). Approximately 5.5 km north of Elk Mountain is Geronimo Ridge. Here pediment (EGP1) occurs at an elevation of 694 m. It extends from northwest to southeast and covers ~450 m².
Table 4.2. The elevation of pediments and knik points observed in Eastern Wichita Mountains.

<table>
<thead>
<tr>
<th>Digital Degrees</th>
<th>Pediment</th>
<th>Elk Mt</th>
<th>Geronimo Ridge</th>
<th>Moko Mt</th>
<th>Mt Pinchot</th>
<th>Mt Scott</th>
<th>North Mt</th>
<th>Rabbit Hills</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEP1 685</td>
<td>EMP1 663</td>
<td>34°43'19.59&quot;N</td>
<td>34°46'53.65&quot;N</td>
<td>34°46'11.23&quot;N</td>
<td>34°44'38.27&quot;N</td>
<td>34°46'53.65&quot;N</td>
<td>34°47'46.61&quot;N</td>
<td>34°46'53.65&quot;N</td>
</tr>
<tr>
<td>EEP2 678</td>
<td>EMP2 680</td>
<td>98°43'19.59&quot;W</td>
<td>98°46'55.73&quot;W</td>
<td>98°40'13.08&quot;W</td>
<td>98°31'54.81&quot;W</td>
<td>98°41'57.27&quot;W</td>
<td>98°45'13.43&quot;W</td>
<td></td>
</tr>
<tr>
<td>EEP3 657</td>
<td>EMP3 663</td>
<td>34°43'21.76&quot;N</td>
<td>34°46'38.63&quot;N</td>
<td>34°46'55.73&quot;N</td>
<td>34°46'53.65&quot;N</td>
<td>34°46'53.65&quot;N</td>
<td>34°46'53.65&quot;N</td>
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<td>Pediment</td>
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<td>751</td>
<td>590</td>
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<tr>
<td>Knik Point</td>
<td>EPP1</td>
<td>722</td>
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<td>590</td>
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<td>655</td>
<td>ENP6</td>
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**Mount Pinchot** - Mount Pinchot is composed of several high hills on the western side of the eastern Wichita Mountains. Pediments are well preserved on Mount Pinchot and on the bordering residual hills. Pediment EPP2 occurs at an elevation of 723 m on the southern side of Mt. Pinchot and on the summit of a hill (34°46'53.65", 34°46'53.65") to the south. Pediment EPP3 is recognized on the same hill at a lower elevation (686 m). Pediment EPP5 is found to the north of the hill at an elevation of 675 m. The pediments vary in the area of 120 m² (EPP2), 280 m² (EPP3), and 500 m² (EPP5). In addition to the pediments, six knik points are also visible on the hills to the south of Mount Pinchot. Along a west-east profile, they show up as low, elongate, and elliptical surfaces at an elevation of ~595 m.

**The Rabbit Hills** - In contrast to other pediments in the eastern Wichita’s, pediments preserved on the Rabbit Hills formed at a lower elevation and are smaller in area. Rabbit Hill, ~2 km south of Mt. Pinchot, occurs along the southwestern edge of the eastern Wichita Mountains and has been highly dissected by local streams (Fig. 3). Pediments ERP1 (584 m) and ERP3 (679 m) occupy 180 m² and 220 m² respectively on the western summits of Rabbit Hill.

**Mount Scott** - Mount Scott, located at northeast end of the eastern Wichita’s, is one of the highest mountains in this region. The only pediment preserved here is the flat top “peak” of Mount Scott at an elevation of 751 m covering an area of ~300 m². Along a north-south profile, a knik point (which may represent a relict pediment) is present at 663 m is also visible along the western side of the mountain. There is a wedge-shaped scarp at the western side of Mt. Scott, along which the surface is gently tilted at ~15° (Appendix 6.) Even though this dipping angle is too steep to be qualified as a pediment, it can be recognized from Google Earth that this scarp at 711m is the piedmont point of pediments. Below this point the slope also shallows again at 687m just above the road. Debris and boulders flows immediately below this area also imply backwearing was an important component of the processes that form the pediments. Thus, below the pediment at the top of Mt. Scott, there is at least the possibility of one or more poorly preserved pediments that have been extensively modified by erosion due to the high elevation.
Figure 4.2. Digital elevation model of Eastern Wichita Mountains, showing topographic profiles along the traces in North Mountain and Moko Mountain respectively. A1, B1) Topographic map with a contour interval of 10 m; A2, B2) Three dimensional surface view color with red-purple stripe. A3, A4; B3, B4) Topographic profile demonstrated along the line of section in A1, B1.
4.4. CORRELATION OF THE ELEVATED PEDIMENTS IN THE WICHITA MOUNTAINS

Pediments are preserved, to various extents, at several distinct elevations throughout the Wichita Mountains (Table 1). A comparison of the elevations of pediments and knik points for the locations investigated by this study demonstrates the presence of at least three major pediment surfaces which can be correlated from the western Wichita Mountains to the eastern Wichita Mountains: Pediment S (665±5 m), Pediment N (685±5 m), and Pediment K (715±5 m) (Fig. 7). Pediment K is preserved on several peaks in Wichita Mountains. Although its scale is limited due to the high elevation (715±5 m), it is found throughout the entire region. Pediment N occurs at an elevation of 685±5 m and is best preserved on the northern mountains (e.g., North Mt., Moko Mt.) in the eastern Wichita’s and Soldier’s Peak in the western Wichita Mountains. Pediment S is a prominent surface commonly in both the western and eastern Wichita’s. Pediment S can be found nearly on very hills in western Wichita at ~660 m. Finally, there is also the possibility of a pediment “R” preserved at a lower elevation of 590±5m in the eastern Wichita Mountains. This pediment is poorly developed or poorly preserved in the western Wichita Mountains (Fig. 7).

Figure 4.3. Correlation of pediment and knik point elevations throughout Wichita Mountains. For probability plot, see appendix 1.
5. DISCUSSION

5.1. CORRELATION of PEDIMENTS

81 % (30/37) of the pediments currently identified in both the western and eastern Wichita Mountains are preserved at the elevation of surface S, N, K, or R (Fig. 7). The correlation of these pediments indicates the likely existence in the past of more extensive surfaces at distinct times throughout Wichita Mountains. Combined with the mechanism of formation pediments, I interpret that both the western and eastern Wichita Mountain belonged to a peneplain before the development of the pediments.

The formation processes for elevated pediments in the Wichita Mountains is reconstructed in Figure 8. Several stages are required to form the pediments: 1) the western and eastern Wichita define a coherent igneous complex (Fig. 8A), upon which a peneplain surface forms. With either a drop in base level or regional tectonic uplift, the ultimate base level declines and exposes the bedrock in this area leading to stream dissection along fractures. 2) After that, there tends to be an episodic quiescence, allowing the ultimate base level to stay at a distinct elevation. This period of stability is necessary for pediments (e.g., Pediment N) to develop by scarp retreat (Fig. 8B). 3) At stage 3, the ultimate base level continues declining and eventually stays at a lower elevation as shown in Fig. 8C. Similar to the erosional process above, another pediment is formed (e.g., Pediment S). Thus, multiple pediments are formed in the Wichita Mountains resulting in a stepped-like nature of the topographic profiles.

The three pediments K, N, and S can be interpreted as remnants of peneplains. This correlation relationship also suggests that the western Wichita Mountain and the eastern Wichita Mountain have behaved as a coherent terrane, undergoing the same exhumation and retreat / transport history during extended periods of tectonic stability resulting in the formation of these surfaces.

The presence of pediments at multiple elevations throughout the Wichita Mountains is consistent with this region undergoing multiple episodic denudation events. A period tectonic quiescence is an essential prerequisite for the development of pediments (Yildirim, 2013). The presence of these surfaces indicates they develop during either separate periods of episodic uplift or changes in base level. Moreover, the three
distinct pediment surfaces demonstrate at least three intervening denudation periods in tectonic history. The aerial extent and scale of each pediment surface may partially reflect the time span of tectonic quiescence. For example, Pediment S is the most widely spread surfaces in Wichita Mountain, may imply the stable tectonic time period to form S was longer than the time period required to form pediments N or R. From this perspective, the regional tectonic history can be reconstructed to some degree.

Figure 5.1. Schematic diagram showing the formation of elevated relict Cenozoic (?) pediments in the Wichita Mountains. The shape of the igneous complex has been idealized.
5.2. REGIONAL PATTERNS AND IMPLICATIONS

The pediments preserved in the western Wichita Mountain were previously suggested to be correlative to the Southern High Plains (Harrell, 1993). The Southern High Plains of Texas are located in the southernmost part of the High Plains section of the Great Plains (Fig. 9). The region is a plateau bounded on the north by the deep valley of the Canadian River and on the east and west by prominent escarpments of at least 100 m (Cronin, 1969). Harrell (1993) suggested that the pediments in Wichita Mountains are correlative to the Southern High Plains with both forming during the Pliocene. This was based upon a linear projection from the Southern High Plains surface coinciding with the elevations of some pediments in the western Wichita Mountains (Fig. 9). Harrell (1993) suggested that during late Pliocene and early Pleistocene, the Southern High Plains retreated westward, for more than 180 km, leaving the behind pediments in the western Wichita Mountains as relicts of the Southern High Plains surface. He did not recognize the existence of pediments in eastern Wichita Mountains as their elevations do not fit along his linear projection.

The results of this investigation demonstrate that correlative pediments developed at multiple distinct elevations in both the western and eastern Wichita Mountains. This suggests that Wichita Mountains behaved as a contiguous crustal block subjected to the same driving forces for pediment formation (e.g., tectonic uplift, change in base level) during the same time periods during the Cenozoic. The linear projection of Harrell (1993) fails to explain both the multi-tiered nature of pediments and the presence of elevated pediments in the eastern Wichita Mountain (Fig. 9).

Crews and Hogan (2004) recognized the possible presence of elevated pediments in the eastern Wichita Mountains. They tried to fit a surface from Southern High Plain to these pediments using an exponential projection as follows:

\[ Z = [-108107*\ln(Y) + 1637269]*\ln(X) + 1352187*\ln(Y) - 20475324 \] (1)
where \( Z \) is in feet and \( X \& Y \) are the UTM coordinates. Using the DEMs constructed for this study the best fit of the elevation data from Wichita Mountains to the elevation of the Southern High Plains is a quadratic polynomial:

\[
F(x) = p_1 x^2 + p_2 x + p_3
\]

(2)

\[
p_1 = 0.009387 \ (0.006908, \ 0.01186) \\
p_2 = -5.183 \ (-6.11, \ -4.255) \\
p_3 = 1321 \ (1246, \ 1397)
\]

Figure 5.2. A) Map of the Southern High Plains region and the Wichita Mountains. B) Topographic profile along line A-B from the Southern High Plains to the Eastern Wichita Mountain. C) Comparison of two projections fitted with elevation data.
Although this projection model provides a better fit for the variation in elevation from the Southern High Plains to the Wichita Mountains, none of these projections accurately reflect the true nature of the erosional surfaces. First, the multiple pediment surfaces at distinct elevations present in Wichita Mountains clearly demonstrate an episodic erosional process, rather than a single event represented by a single surface. Second, this projection assumes that the pediment(s) in Wichita Mountains and the Southern High Plain were denudated at the same time – the presence of multiple surfaces increases the uncertainty in which, if any, of the surfaces in the Wichita Mountains can be correlated to the Southern High Plains. Without age constraints for these surfaces in the Southern High Plain or in the Wichita Mountains, it is difficult at best to match these different surfaces based upon their characteristics of being sub-horizontal surfaces and the piedmont angle within them.

Estimates of erosion rates for the Southern High Plain differ from those for the Wichita Mountains. Based on apatite fission-track analysis, recent denudation in the Wichita Mountains began at some time in the Paleogene (55-25 Ma) (Winkler et al., 1999). The onset of denudation decreases dramatically from Wichita area westwards. In east-central New Mexico (i.e., the western side of the Southern High Plains) the onset of denudation is estimated to be 35-12 Ma and decreasing towards the west. At the same time, the amount of erosion has increased from ~1 km in Wichita area to ~3 km westwards. Carter et al. (1998) suggested ~1.5 km of material was removed by erosion from the Wichita Mountains over the last 40-50 Ma. Evidence from Ouachita trend indicated that the total erosion is ~1 km during the last ~ 40 Ma (Corrigan et al, 1998). Erosion rates for these two areas can be calculated using equation 3:

\[ R = \frac{A}{T} \]  

(R is erosional rate; A is the amount of erosion; T is time span)

Calculated erosion rates for the Wichita Mountains using equation 3 is 18-40 m/Myr whereas those for the Southern High Plains in the west is 85-250 m/ Myr. However, based upon the east-west topographic profile and three different projections, the erosion
rate in the Wichita area is much larger than that in High Plain, if it forms from the west
dipping topography. This large difference in erosion rates between the two provinces
undermines the initial assumption that the erosional surface from Wichita Mountains to
Southern High Plain is age correlative.

5.3. UNCORRELATED PEDIMENTS

In the Wichita Mountains there are several pediments and knik points which are
preserved locally on one mountain but are yet to be recognized on other peaks. There are
several hypotheses that may explain the presence of isolated pediments and knik points.
First, alternation between fluvial terraces and pediments suggest that parts of the
pediments and knik points are formed by fluvial processes connected to local rivers rather
than regional tectonics. Second, pediments and knik points at the higher elevations (more
than 720 m) are more susceptible to removal by erosion reducing the potential for
correlation. Third, fractures are highly developed throughout Wichita Mountains; the
offsets of local faults may result in vertical displacement or tilting of some pediments
obscurring the original correlation. These possibilities, as applied to the Wichita
Mountains are discussed in the following sections.

5.3.1. Sub-horizontal Surfaces of Alluvial Fans. Alluvial fans have similar
topographic features as pediments in DEMs and topographic maps. Although the relative
spatial resolution (~9 m) of the available DEM proved to be accurate enough to highlight
the pattern and nature of pediments in Wichita Mountains, DEM-based correlations have
some limitations due to the impact of several other factors which will be discussed below.
The distortion of elevation data makes it difficult to distinguish pediments from alluvial
fans. The elevation data is draped directly over the DEMs, but the method is also prone to
errors because of the vertical exaggeration difference and distortions when viewing areas
away from the immediate center point. They slope down and take the form of low angle
rock fans that commonly merge along the mountain front. Thus it is possible that some
sub-horizontal surfaces which are rock fans may have been mistaken for pediments. The
similarity between the morphology of pediments and alluvial fans in the DEM these
features. For example, the elevations of surfaces which represent alluvial fans that
developed locally or in isolation are more likely to fail to correlate with other surfaces
throughout Wichita Mountains. For example, the incised pediments are mingled with
alluvial fans in the Rabbit Hills due to the proximity to the highly developed Red River
system (Fig. 9).

5.3.2. Displacement due to Local Deformation. Movement along faults
subsequent to the development of pediments may be responsible for creating pediments at
elevations that do not correlate with other surfaces. After the late Cenozoic, most of the
faults in this region are inactive or record small displacements (Budnik, and Davis, 1985).
However, movement along faults locally has displaced pediment surfaces. For example,
the Burch Fault can be seen to displace a pediment surface at least 30 m, rendering a step
in elevation as seen in Figure 9B. It is possible that similar movement along faults could
impact the correlation of the pediments in Wichita Mountains.

5.3.3. Erosion at High Elevation. Pediments preserved at higher elevations may
be eroded away locally. There is an absence of pediments elevated above 725 m in
western Wichita Mountains, which makes it impossible to completely correlate the
elevation between western and eastern Wichita Mountains. However, the elevation of
peaks in western Wichita Mountains is commonly around 720 m (e.g., Soldier’s Peak)
suggesting these peaks may represent the last vestiges of the higher elevation pediment
still preserved in the eastern Wichita Mountains (Fig. 8).

5.4. POSSIBLE MECHANISM FOR PEDIMENTS FORMATION IN THE
WICHITA MOUNTAINS

Several major regional events that affected the North American mid-continent
may be associated with the erosion processes in Wichita Mountains. Based upon the
tectonic history, the pediments are formed as a result of interplay between base level,
climate change, and tectonic uplifting in Pennsylvanian time and/or Cenozoic time. The
latter event (Cenozoic time) forms the focus of this paper.
5.4.1. **Changes of Base Level.** A drop in base level and associated large scale denudation in Tertiary time possibly triggered the formation of the pediments in Wichita Mountains. Changes in base level will result in a decline of the water table, which will leads to dissection of older peneplain surfaces. By this process, the formation of pediments commences in the bedrock of the Wichita Mountains igneous complex.

Based upon Corrigan et al., (1998) the base level dropped 200 m in late Cretaceous. This triggered a denudation of 100-140 m of elevation in the Ouachita Trend. However, Corrigan (1988) estimated more than 1km strata had been removed away along Ouachita trend of Cretaceous to Paleogene during Tertiary time. Winkler et al. (1999) also inferred that 0.5-1.5 km of denudation of deposits have occurred in Anadarko Basin, Oklahoma. Therefore, changes of base level are a necessary but not a sufficient condition for the formation of the pediments in Wichita Mountains and relative erosional process according to the conceptual model of this paper.

5.4.2. **Changes of Climate.** The climate history in Cenozoic shows the possibility that the change of climate contributes to the formation of the pediments in Wichita Mountains (Winkler et al., 1999). Gregory and Chase (1994) attributed the formation of erosional surfaces in the Southern Rocky Mountains and northern High Plains primarily to the climate change, because the climate became warm, humid, and equitable in Late Eocene. Their numerical model showed that this climate factor was mechanism for formation of low-relief, high-level surfaces without incision. However, other researchers (Hay et al., 1989) suggest that the climate factor is too weak to be the principal driving force. Therefore, it is still not clear whether changes of climate is the first order effect for the development of pediments in the Wichita Mountains.

5.4.3. **Tectonic Factors.** Based upon the AFT analysis, the tectonic uplift rate is 10m/Myr to achieve the current elevations of the High Plain (Corrigan et al., 1998). The regional uplift is likely to be driven by tectonic movement to the west in Colorado and New Mexico (Winkler et al., 1999). There are three possible tectonic mechanisms leading to the development of erosional surfaces in this region: 1) the isostatic response after Laramide deformation, 2) uplift related to crustal thinning associated with formation of the Rio Grande Rift, and 3) dynamic topography.
**Laramide deformation.** The regional tectonic uplift can be attributed to the Laramide deformation. Cross (1978) suggested that the lithosphere formed during low-angle subduction associated with Laramide deformation tended to uplift, because large amount of low density deposition lead to isostatic respond after the subduction stopped. Based on this theory, Mitrovica et al., (1989) concluded that this high elevation topography was a result of rebound of isostatic equilibrium in the Neogene after the deposition of a thick layer of low density sediments in Late Cretaceous to Paleogene time. During the middle Cenozoic, the elevation has increased 2 km in the region of southern Rocky Mountains and 0.5 km in the High Plain west of the Wichita Mountains (Winkler et al., 1999). Bird (1988) pointed out that the lithosphere under the High Plains has been thickened due to the low angle subduction during Laramide deformation. This process resulted in asthenosospheric upwelling and recent uplift. Spencer (1996) found the model of Bird was inconsistent with seismic and geochemical evidence, so he modified Bird’s model and indicated that the presence of Proterozoic mantle lithosphere beneath the Colorado Plateau during the low-angle subduction. He further stated that the 800 m elevation of the High Plains near the Southern Rocky Mountains front was caused by isostatic respond after the low density sediments have been removed away. Thus, the Laramide Orogeny can be interpreted as driving force to explain the generation of the late Cretaceous-early Tertiary shortening and uplift on the southern margin of the North American plate.

**Crustal thinning related to Rio Grande rift.** Geophysics studies suggest that the denudation in Wichita area was caused by crustal thinning related to Rio Grande rift (Winkler et al., 1999). Rio Grande Rift is a Cenozoic north trending continental rifts system, separating Colorado Plateau from the interior of the North American craton (Kil and Wendlandt, 2004). Regional topography and continental evolution is potentially controlled by this extensive process due to the crustal thinning and continental breakup (Wilson et al., 2005). Eaton (1987) also pointed out that the uplift may be influenced by the upwelling of the mantle associated with crustal thinning. The evidence from seismic studies suggests ~10 km crustal thinning by pure shear extensional mechanism for the Rio Grande Rift lithosphere (Wilson et al., 2005). Moreover, a series of seismic studies (Sheehan, 1995; Lee and Grand, 1996) have indicated that the mantle beneath the Rio
Grande Rift and the South Rocky Mountains is hot, active and buoyant, which is necessary to support the high elevated topography and lead to the uplift. Therefore, the upwelling of magma under Rio Grande rift is responsible for the crustal thinning and regional uplift from Great Plain west to Wichita Mountains.

**Dynamic mantle support.** The uplift can also result from “dynamic mantle support” (Winkler et al., 1999). Regional long-term uplift, such as that presented in Southern Rocky Mountains and the High Plains, is commonly formed from flow in the mantle (Lithgow, and Gurnis, 1997). Based upon the model of Lithgow and Gurnis (1997), such broad uplift was associated with return flow near the descending slabs in the mantle. The model illustrates the uplift during the Cenozoic on the North American craton, including both Wichita area and Southern High Plain, and toward the north until it reaches the maximum in the Canadian Shield.
The existence of pediments in Wichita Mountains has been confirmed by DEMs. These pediments are defined by four principal factors: 1) a dipping angle from 0.5 to 7°, 2) a minimum scale of 84 m wide, 3) association with piedmont angle, and 4) underlain by the Wichita Granite Group. Based on the DEMs, the pediments were recognized at multiple elevations representing at least three distinct surfaces: S (665±5 m), N (685±5 m), and K (715±5 m) in both western and eastern Wichita Mountains.

The correlation between pediments in the western and eastern Wichita Mountains demonstrates a previously unrecognized common geomorphic history for these two areas. 81% of the pediments can be correlated throughout western and eastern Wichita Mountains. It demonstrates that the basement likely behaved as a coherent block when these surfaces were forming.

The mechanism of pediment formation in the Wichita Mountain is still unclear. The possible factors controlling the elevated pediments surfaces include changes in base-level, climate change, and tectonic uplift in Mid-Cenozoic.

The results of this study indicate that the correlation of horizontal surfaces in the Wichita Mountains to the Southern High Plain is tentative at best. Radiogenic helium dating should be employed to further correlate the pediments in Wichita Mountains with the surface of the Southern High Plain. It may yield an estimate of the timing of the erosional events in Wichita and provide detailed constraints on the recent exhumation history. These results may also be related to larger scale tectonic process to give us insight to the geologic history of the southern Mid-continent.
## APPENDIX

### 1. Classification and Formation of Pediments

Table 7.1. Table of Classification of pediments. (Summaried from Twidale, 2005)

<table>
<thead>
<tr>
<th></th>
<th>Sedimentary Pediment</th>
<th>Mantled pediment</th>
<th>Platform(Rock Pediment)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Terrain</strong></td>
<td>Sedimentary</td>
<td>Granitic rocks</td>
<td>Granitic rocks</td>
</tr>
<tr>
<td><strong>Layer of coverage</strong></td>
<td>Allochthonous debris</td>
<td>A mantle from weathering of local bedrock</td>
<td>No cover of unconsolidated material</td>
</tr>
<tr>
<td><strong>Basic unit</strong></td>
<td>Sedimentary rocks</td>
<td>A thin layer of low-angle, fan-shaped, cone segment, most derived from weathering of bedrock or streams</td>
<td>No coverage units, but some have remnants of a regolith</td>
</tr>
<tr>
<td><strong>Surface feature</strong></td>
<td></td>
<td>Stand in isolation or aprons, or merged with similar features to form low-angle cones</td>
<td>Inclined, dimpled and grooved surfaces with some fringe uplands, or stand in isolation as reduced remnants or domes of once high mass.</td>
</tr>
<tr>
<td><strong>Relationship between sedimentary and mantled pediment</strong></td>
<td>Both of sedimentary pediments and mantled pediments are surfaces of transportation, which are shaped by erosion and deposited by wash and rill.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Relationship between mantled and rock pediment</strong></td>
<td>Bryan (1927) addressed that the mantled and rock pediments are end members of a continuum. It is the relationship between the rate of lowering of weathering front and mantle surface that dominates the thickness of the regolith. If the rate outpaces the mantle, the mantle surface will be thick; otherwise, the front will be exposed as rock pediment.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7.2. Table of Mechanism of pediments

<table>
<thead>
<tr>
<th>Pediment development</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scarp recession</td>
<td>Backwearing of Inselberg, less resistant rocks will erode faster, while the surface of more resistant rocks will be left as pediments.</td>
</tr>
<tr>
<td>Mountain downwearing</td>
<td>No retreat perpendicular to the floor, only physical weathering horizontally.</td>
</tr>
<tr>
<td>Two-stage etching</td>
<td>Stage 1, granite block will be under fracture-controlled subsurface weathering. Stage 2, the corestones/inselbergs will be exposed by different erosion and the grus will be evacuated.</td>
</tr>
</tbody>
</table>
Elevation data in Wichita Mountains

Table 7.3. Elevation data of pediments in Western Wichita Mountains

<table>
<thead>
<tr>
<th>Name of pediment</th>
<th>Elevation(M) Based on</th>
<th>Lat</th>
<th>Lon</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Mountain</td>
<td>652-661</td>
<td>Contour Map 34°52'15.58&quot;</td>
<td>99°17'37.31&quot;</td>
</tr>
<tr>
<td>Flattop Mountain</td>
<td>652-664</td>
<td>Contour Map 34°51'39.75&quot;</td>
<td>99°14'54.39&quot;</td>
</tr>
<tr>
<td>Soldiers Peak</td>
<td>652-678</td>
<td>DEM 34°50'25.57&quot;</td>
<td>99°14'30.96&quot;</td>
</tr>
<tr>
<td>Riverside Mountain (No name)</td>
<td>530-540</td>
<td>Contour Map 34°55'06.11&quot;</td>
<td>99°12'33.06&quot;</td>
</tr>
<tr>
<td>Tepee Mountain</td>
<td>652-660</td>
<td>DEM 34°52'38.89&quot;</td>
<td>99°14'30.96&quot;</td>
</tr>
<tr>
<td>Quatz Mountain</td>
<td>545-576</td>
<td>Contour Map 34°54'14.90&quot;</td>
<td>99°19'15.95&quot;</td>
</tr>
</tbody>
</table>
Table 7.4. Elevation data of pediments in Eastern Wichita Mountains

<table>
<thead>
<tr>
<th>Name of pediment</th>
<th>Elevation(M)</th>
<th>Based on</th>
<th>Lat</th>
<th>Lon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moko Mt(A)</td>
<td>673.5-679.5</td>
<td>Contour Map</td>
<td>34°46'11.23&quot;</td>
<td>98°40'13.08&quot;</td>
</tr>
<tr>
<td>Moko Mt(B)</td>
<td>665-664</td>
<td>Contour Map</td>
<td>34°46'11.23&quot;</td>
<td>98°40'13.08&quot;</td>
</tr>
<tr>
<td>Moko Mt(C)</td>
<td>670.5-680</td>
<td>Contour Map</td>
<td>34°46'11.23&quot;</td>
<td>98°40'13.08&quot;</td>
</tr>
<tr>
<td>Moko Mt(D)</td>
<td>664.5-667.5</td>
<td>Contour Map</td>
<td>34°46'11.23&quot;</td>
<td>98°40'13.08&quot;</td>
</tr>
<tr>
<td>Moko Mt(E)</td>
<td>686-692</td>
<td>Contour Map</td>
<td>34°46'11.23&quot;</td>
<td>98°40'13.08&quot;</td>
</tr>
<tr>
<td>North Mt(A)</td>
<td>667.5-679.5</td>
<td>Contour Map</td>
<td>34°47'46.61&quot;</td>
<td>98°41'57.27&quot;</td>
</tr>
<tr>
<td>North Mt(B)</td>
<td>655-661.5</td>
<td>Contour Map</td>
<td>34°47'46.61&quot;</td>
<td>98°41'57.27&quot;</td>
</tr>
<tr>
<td>North Mt(C)</td>
<td>680-689</td>
<td>Contour Map</td>
<td>34°47'46.61&quot;</td>
<td>98°41'57.27&quot;</td>
</tr>
<tr>
<td>North Mt(D)</td>
<td>664.5-680</td>
<td>Contour Map</td>
<td>34°47'46.61&quot;</td>
<td>98°41'57.27&quot;</td>
</tr>
<tr>
<td>North Mt(E)</td>
<td>685.8-691.9</td>
<td>Contour Map</td>
<td>34°47'46.61&quot;</td>
<td>98°41'57.27&quot;</td>
</tr>
<tr>
<td>North Mt(F)</td>
<td>682.7-685.8</td>
<td>Contour Map</td>
<td>34°47'46.61&quot;</td>
<td>98°41'57.27&quot;</td>
</tr>
<tr>
<td>Geronimo Ridge</td>
<td>685.5-698</td>
<td>Contour Map</td>
<td>34°46'38.63&quot;</td>
<td>98°42'55.73&quot;</td>
</tr>
<tr>
<td>Rabbit Hills(A)</td>
<td>609.6-618.7</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>98°45'13.43&quot;</td>
</tr>
<tr>
<td>Rabbit Hills(B)</td>
<td>579.1-588.2</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>98°45'13.43&quot;</td>
</tr>
<tr>
<td>Rabbit Hills(C)</td>
<td>582.1-588.2</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>98°45'13.43&quot;</td>
</tr>
<tr>
<td>Mt Pinchot(A)</td>
<td>716.2-725.4</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>34°46'53.65&quot;</td>
</tr>
<tr>
<td>Mt Pinchot(B)</td>
<td>670.5-682.7</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>34°46'53.65&quot;</td>
</tr>
<tr>
<td>Mt Pinchot(C)</td>
<td>670.5-679.7</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>34°46'53.65&quot;</td>
</tr>
<tr>
<td>Mt Pinchot(D)</td>
<td>716.2-725.4</td>
<td>Contour Map</td>
<td>34°46'53.65&quot;</td>
<td>34°46'53.65&quot;</td>
</tr>
<tr>
<td>Mt Scott</td>
<td>746.8-749.8</td>
<td>Contour Map</td>
<td>34°44'38.27&quot;</td>
<td>98°31'54.81&quot;</td>
</tr>
<tr>
<td>Elk Mt</td>
<td>669.5-684.9</td>
<td>DEM(Need Map)</td>
<td>34°43'21.76&quot;</td>
<td>98°43'19.59&quot;</td>
</tr>
</tbody>
</table>
Distribution diagram

The elevations of pediments in both western Wichita and eastern Wichita have been collected. Then the distribution diagram of these elevations also has been made. To correlate the elevations of eastern and western Wichitas, we first make sure the elevation range of a pediment. I use a tolerance of 7 meters, which means pediments with elevation at ±7 m are considered as at same elevation. Next, we need calculate the elevation frequency of the pediments developed in West and East respectively. If most of the pediments in West and East fall into the same elevation ranges, it means they can be correlation to particular elevation. In this case, the interval to calculate the frequency would be important. After several tentative tests, we nailed down the interval as 6 meters, making the elevation distribution easier to interpret.

![Figure 7.1. Correlation result from pediments elevation data](image-url)
Figure 7.2. Correlation result from pediments and knik points elevation data.
Figure 7.3 Illustration of mechanism of pediment formation
Calculation of the dipping angle throughout Wichita Mountains

Figure 7.4. Calculation of Dipping angle of the pediments in Wichita Mountains
Figure 7.5. Cross section of Wichita Mountains
DEMS of Wichita Mountains.

Figure 7.6. Topographic map of flattop mountain
Figure 7.7. Topographic Profile #1 in Flattop Mountains

Figure 7.8. Topographic Profile #2 in Flattop Mountains
Figure 7.9. Topographic Profile #3 in Flattop Mountains

Figure 7.10. Topographic Profile #4 in Flattop Mountains
Figure 7.11. Topographic Map of Tepee Mountain.
Figure 7.12. Topographic Profile #1 in Tepee Mountain

Figure 7.13. Topographic Profile #2 in Tepee Mountain
Figure 7.14. Topographic Profile #3 in Tepee Mountain.
Figure 7.15. Topographic Map of Elk Mountain
Figure 7.16. Topographic Profile #1 in Elk Mountain

Figure 7.17. Topographic Profile #2 in Elk Mountain
Figure 7.18. Topographic Profile #3 in Elk Mountain
Figure 7.19. Topographic Map of Geronimo Ridge
Figure 7.20. Topographic Profile#1 in Geronimo Ridge
Figure 7.21. Topographic Map of Mountain Pinchot.
Figure 7.22. Topographic Profile#1 in Mountain Pinchot.

Figure 7.23. Topographic Profile#2 in Mountain Pinchot.
Figure 7.24. Topographic Profile#3 in Mountain Pinchot.

Figure 7.25. Topographic Profile#4 in Mountain Pinchot.
Figure 7.26. Topographic map of Mountain Scott.
Figure 7.27. Topographic Profile#1 in Mountain Scott.
Figure 7.28. Topographic map of Rabbit Hill
Figure 7.29. Topographic map of Rabbit Hills
Figure 7.30. Topographic Profile#1 in Rabbit Hills

Figure 7.31. Topographic Profile#2 in Rabbit Hills.
Figure 7.32. Topographic Profile#1 in Rabbit Hills.

Fractures in Wichita Mountains

Figure 7.33. Structure distribution in Rabbit Hills and North Mountains (extracted from Pro Google Earth)
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